BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description: Actively mode-locked, frequency quadrupled Nd: Vanadate laser used in a study of a super conducting RF electron gun and of room temperature photo cathodes.
Location: BLDG 939

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:

Name: A. Burrill/T. Srinivasan-Rao *Signature:* *Date:* 10,sept 2003

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

C. Weilandics

BNL LSO printed name *Signature* *Date*

ES&H Coordinator printed name *Signature* *Date*

APPLICABLE LASER OPERATIONS
☒ General Operation ☐ Alignment ☐ Service/Repair ☐ Specific Operation ☐ Fiber Optics

ANALYZE THE LASER SYSTEM HAZARDS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system.

LASER SYSTEM CHARACTERISTICS					
Laser Type *(Argon, CO2, etc)*	Wavelengths	ANSI Class	Maximum Power of Energy/Pulse	Pulse Length	Repetition Rate
Nd:Vanadate	266 nm	IV	0.2W	approx.10ps	81.25 MHz

☐ **Cryogen Use**

Describe type, quantity, and use.

NONE

☐ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

NONE

x **Electrical Hazards**

Description *(Describe the power supply to the system).*

The commercial power supply of the laser drives the diode bar that optically pumps the Nd: Vanadate crystal in the laser. The electrical specifications of the power supply are: Nominal voltage 100-240 VAC, Power consumption: 400 VA Nominal frequency 50-60 Hz

x **Other Special Equipment**

Description *(Equipment used with the laser(s)).*

Nd: Vanadate is pumped by a fully enclosed diode bar, which is powered by the power supply mentioned above

Laser System Configuration: Describe the system controls *(keys, switch panels, computer controls),* beam path and optics *(provide a functional/block diagram for complicated beam paths)*.

The laser is a commercial (Time-Bandwidth products) diode pumped solid state (Nd:Vanadate) laser actively mode-locked at 81.25 MHz. The output characteristics of the laser is as follows:

Wavelength:	1.06 μm
Max. Average power:	10 W
Repetition rate:	81.25 MHz
Spot size:	0.6 mm (FWHM)

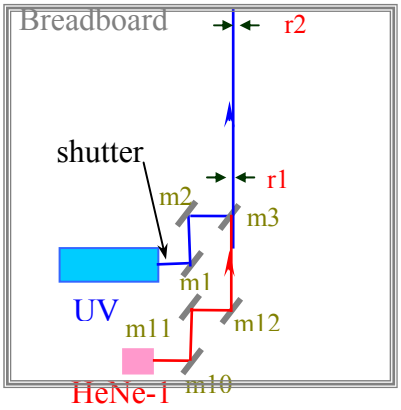
This output is passed through two frequency-doubling crystals that convert the infra red radiation to UV. The unconverted infrared and green radiation are blocked completely by the housing of the laser. The radiation exiting the laser has the following characteristics:

Wavelength:	0.266 μm
Max. Average power:	200 mW
Repetition rate:	81.25 MHz
Spot size:	0.6 mm (FWHM)
Pulse duration:	10 ps

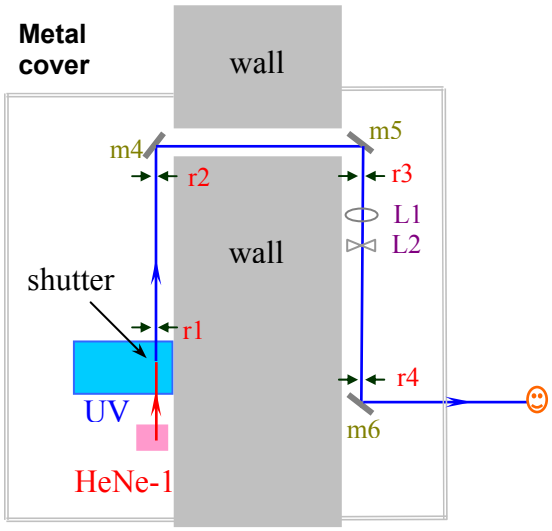
The laser is anchored to an optical breadboard vertically mounted to the 13' thick concrete wall separating the experimental hall and the laser room. In the laser room the laser and the transporting optics for the gun are completely enclosed in a metal box that is opaque to 0.266 μm radiation. In addition the laser may be used to study room temperature photo cathodes using an open beam transport in the laser room. The beam to the gun is transported through the shield wall into the experimental hall, where there is a partially open transport to the gun.

A schematic of the laser beam transport is shown in Figure 1. Initial alignment of the transport optics will be accomplished using a low power alignment HeNe. The UV mirrors adjacent to the laser are then aligned so that the 0.266 μm beam is collinear to the HeNe beam. The irises along the beam line are used to check the alignment periodically.

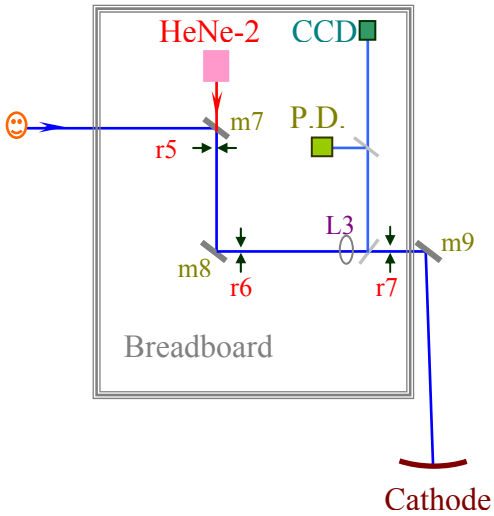
Figure 1 Schematic of the laser beam transport. Alignment mirrors:m10-m13, UV mirrors: m0-m9, Irises: r1-r7, lens: l1-l3



a) laser room (straight-view)



b) wall area (side-view)



c) experimental hall (top-view)

DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures	☐ Protective Housing Interlocks	☐ Other
☒ Beam Stop or Attenuator	☒ Key Controls	
☐ Activation Warning System	☐ Other Interlocks	
☐ Ventilation	☒ Emission Delay	

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **Attach a copy of the design review documentation and a written testing protocol. Attach or keep elsewhere any completed interlock testing checklists to document the testing history.**

Engineering Controls Description:

Engineering Controls Description:
Beam Enclosure: The optical breadboard is enclosed by a metal box. During routine operation, this box will be in place. Warning signs appropriate to the laser will be posted on this box. Access door to the experiment hall and the laser room will interlock the laser.
Emission Delay: Delayed opening of the shutter will be preceded by audio warning.
Beam stop or attenuator: The infra red and the green beam generated by the laser are completely blocked by the wall of the laser cavity and is incorporated in the cooling loop so that neither the radiation nor the heat generated at the beam stop are safety issues. The beam stop immediately outside the laser is made of sand blasted metal to block the UV and reduce specula reflection.
Interlock: The beam stop immediately outside the laser is part of the interlock system (see attached schematic). The room doors will close the beam stop, if opened without the bypass key. Access to the rooms will be limited at all times to authorized personnel only, using key control. Warning light outside the laser room will be on when the laser is on. The interlock system will be tested periodically by the Access Control Group of CAD [E-Cooler Laser Interlock Test Procedure] and the status will be recorded in the logbook kept in the laser room.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☐ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOP) are required for laser system operation, alignment, and maintenance. The SOPs need only contain the steps necessary to perform these tasks and identify when and where posting and personal protective equipment is required. SOPs must be approved by the BNL Laser Safety Officer and should be kept with this program documentation.

Administrative Controls Description:

Signs: specifying the gain medium, emission wavelengths, power and repetition rates will be posted both outside the laser room, experimental hall and outside the metal box enclosing the optical beam lines.

Labels: labels specifying the output parameters are posted on the laser itself.

Warning light: outside the laser room will be on when laser shutter is on

Also see attachment 1.

CONFIGURATION CONTROL

Prepare and attach a checklist to be used for configuration control of any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Include entries to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

See attachment 2.

PERSONAL PROTECTIVE EQUIPMENT

☒ Eye Wear ☐ Skin Protection

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.
Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE), describe the nature of the hazard and the steps that will be taken to protect against the hazard.

EYE WEAR SPECIFICATIONS			
Laser System Eyewear Identification	Wavelengths	Intra-beam Optical Density	Diffuse Optical Density
Nd:Vanadate	266nm	OD 20	
	532 nm	OD 7	
	1060nm	OD 14	

Eyewear shall be worn during UV alignment and trouble shooting/maintenance

EYE WEAR REQUIREMENTS				
Laser Type *(Argon, CO2, etc)*	Wavelengths	Intra-beam Optical Density	Diffuse Optical Density	NHZ
Nd:Vanadate	266 nm	5.7 OD(10 sec.)	2.2 OD (600 sec.)	2.6 meters

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the BNL World Wide Web based training course (BNL course #HP-IND-011).

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered
  - Review of this program documentation
  - Review of SOPs

All laser safety training must be repeated every two years.

MEDICAL SURVEILLANCE

Operators of ANSI Class 3b and 4 laser systems must complete a baseline medical eye examination prior to laser system operation. Any qualified ophthalmologist may complete this exam. BNL has arranged for this service from the following local physicians:

Dr. Charles Rothberg 331 East Main St. Patchogue, NY 11772	The Ophthalmic Center Dr. Basilice 3400 Nesconset Highway East Setauket, NY 11733	East End Eye Associates Dr. Sherin 669 Whiskey Road Ridge, NY 11961
631 758-5300 $65 per exam	631 751-2020 $60 per exam	631 369-0777 $125 per exam

Personnel using physicians other than those listed must have their examination records forwarded to the BNL Occupational Medicine Clinic.

FEEDBACK AND IMPROVEMENT

Comments and suggestions for improvement should be directed to BNL-Laser Safety Officer, Chris Weilandics (X2593; weil@bnl.gov).

LASER USER QUALIFICATION

Personnel qualified to work with this laser system are listed below. These Qualified Laser Operators must understand the information and conform to the requirements contained in this document. For training and medical surveillance, enter the date of completion.

Qualified Laser Operators:

Basic Laser Training	Job-Specific Training	Medical Surveillance	Printed Name	Signature	Owner/Oper. Initial/date
12/29/00	3/9/01	5/20/85	T. Srinivasan-Rao		
1/8/03	1/15/03	3/26/03	A. Burrill		

Attachment 1

SOP for the SCRF injector: Laser

The laser is a commercial (Time-Bandwidth products) diode pumped solid state (Nd:Vanadate) laser actively mode-locked at 81.25 MHz. The output characteristics of the laser is as follows:

Wavelength:	1.06 μm
Max. Average power:	10 W
Repetition rate:	81.25 MHz
Spot size:	0.6 mm (FWHM)

This output is passed through two frequency-doubling crystals that convert the infra red radiation to UV. The unconverted infrared and green radiation are blocked completely by the housing of the laser. The radiation exiting the laser has the following characteristics:

Wavelength:	0.266 μm
Max. Average power:	200 mW
Repetition rate:	81.25 MHz
Spot size:	0.6 mm (FWHM)
Pulse duration:	10 ps

The laser is anchored to an optical breadboard vertically mounted to the 13' thick concrete wall separating the experimental hall and the laser room. The laser and the transporting optics in the laser room are completely enclosed in a metal box.

A schematic of the laser beam transport is shown in Figure 1. Initial alignment of the transport optics will be accomplished using a low power alignment HeNe. The UV mirrors adjacent to the laser are then aligned so that the 0.266 μm beam is collinear to the HeNe beam. The irises along the beam line are used to check the alignment periodically.

Normal operating procedure:

Under normal operating conditions, the laser beam path deviation, spot size, pulse duration and energy are measured at the start up and monitored regularly. Once the system's alignment has been verified, normal operation consists of monitoring the output using a power meter during start up and a photodiode as on-line detector

I. Laser beam path alignment procedure:

I.1 With the box closed, observe the position of the UV beam on irises 1-7 visually and monitor the image of the cathode on the monument using the video camera

I.2 If the beam is well centered on the irises and at the correct location on the monument, the alignment is fine. Proceed to measure the spot size.

I.3 If the beam is misaligned, use the irises to identify the mirrors that need to be adjusted. Block the UV beam at the exit of the laser using the retractable beam block. Adjust the mirrors so that the red HeNe beam is well centered on the irises.

I.4 Unblock the UV and check for the co linearity of UV and red beams. If not collinear, turn the knobs in the first two mirrors on the UV beam path to restore colinearity.

I.5 Check the laser spot on the video camera to ensure that the laser irradiates the cathode at the correct location. If not repeat steps 1-5

II. Laser spot size on cathode:

The video image is also used to measure the spot size of the laser on the cathode. This spot size is determined by the initial laser spot size, the divergence of the laser, the focal length and location of the imaging optics and the location of the monument. During normal operation, none of these are expected to change, and hence need not be adjusted routinely.

Record the spot size seen by the camera displayed on the video monitor

III. Laser energy:

A power meter is used to measure the average power of the laser at the start up and a calibrated photodiode is used for subsequent monitoring.

III.1 Block the UV beam

III.2 Insert the power meter in the UV beam path close to the laser

III.3 Unblock the UV

III.4 Measure and record the average power of the laser. If it meets the requirement, proceed to step 5. Any deviation of the laser power from the specified value requires laser troubleshooting and is not a part of routine operation.

III.5 Block the UV and remove the power meter

III.6 Unblock the UV

III.7 Monitor the power using photodiode

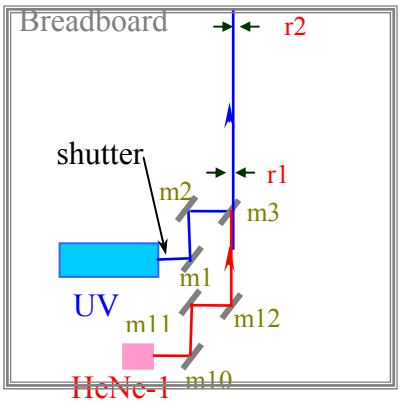
IV Pulse Duration:

The laser pulse duration is monitored online, using an autocorrelator. Any deviation of the pulse duration from the specified value requires laser trouble shooting and is not a part of routine operation

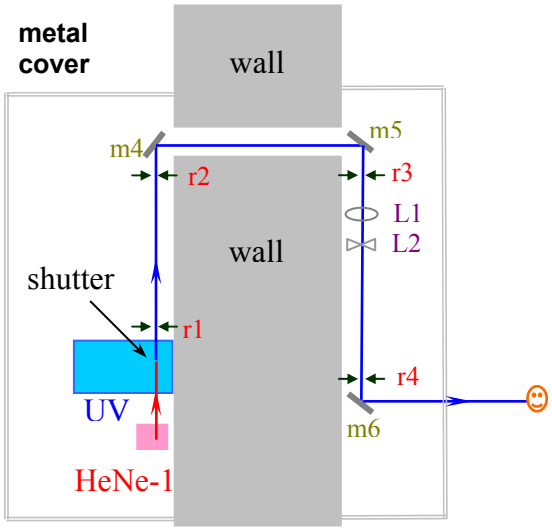
Initial alignment and Trouble shooting the laser:

During this process, the metal box enclosing the laser and the transport optics may have to remain open. The entrance door will be monitored such that when the door is opened, the laser will be blocked after a 30 second delay. Troubleshooting procedure established by the vendor will be followed. Troubleshooting will be done either by the representative of the vendor or qualified BNL personnel

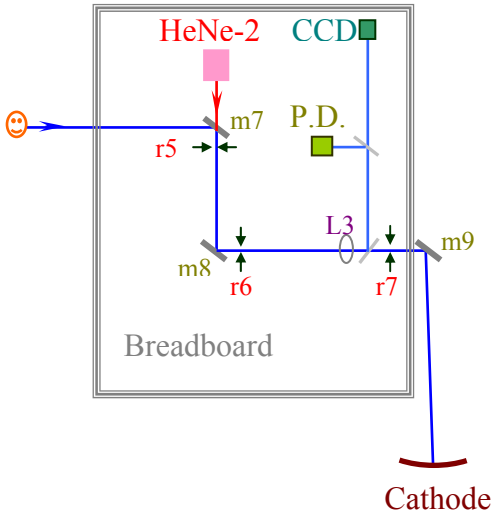
Figure 1 Schematic of the laser beam transport. Alignment mirrors:m10-m13, UV mirrors: m0-m9, Irises: r1-r7, lens: l1-l3



a) laser room (straight-view)



b) wall area (side-view)



c) experimental hall (top-view)

Training:
All authorized personnel will undergo basic laser training, site-specific laser training and laser eye exam prior to being authorized to handle the laser beam. The basic training is a web-based course covering basic laser hazards and handling procedures. The topics covered in the site specific training would include the specific type and characteristics of the laser being used, appropriate protective wear and operation of the interlock system. A doctor's report on the eye exam will be on file prior to handling the laser.

Attachment 2

Configuration Control Checklist

The following laser beam configuration controls should be in place prior to normal operation of laser into experimental hall (see figure 1 for details).

1. ____ Beam stop shutters in place and operational
2. ____ Mirrors M1-M12 in place
3. ____ Metal box in place with irises open
4. ____ Beamspliter leading to CCD and photodiode in place
5. ____ Laser warning signs in place on doors to the laser room and the experimental hall as well as on the Laser and metal enclosures.
6. ____ Laser interlock and warning lights operational and tested
7. ____ Laser cover in place and interlock not defeated
8. ____ All personnel in the laser room and the experimental hall must be authorized and trained in the use of the laser and must be wearing the appropriate eyewear.
9. ____ Visually inspect the laser beam path for obstructions.
10. ____ Ensure the CCD camera and Photodiode are in place.

Operators Name: (print)_____ date:_____

Signature:_____

Attachment 3

LASER SYSTEM-SPECIFIC TRAINING CHECKLIST

Laser User:	
Laser Owner:	
Laser System:	

Topic	User Signature / Date	Owner Signature / Date
General Laser Safety • Laser classifications • Laser hazards • Maximum permissible exposure • Good practice in the lab		
Interlock Instruction • Configuration • Operation		
Description of Laser Output Characteristics • Wavelength • Pulse energy • Average power		
Associated electrical hazards • Power supply • PMT detectors		
Normal Operation • Power on/off • Shutter operation • Normal experimental configuration • Nominal hazard zone		
Non-Normal Operation • Gross alignment • Troubleshooting		